N° XXIV.

An Optical Problem, propoſed by Mr. HOPKINSON, *and ſolved by* Mr. RITTENHOUSE.

Philadelphia, March 16th, 1785.

DEAR SIR,

Read Feb. 17, 1786. I TAKE the liberty of requeſting your attention to the following problem in *optics*. It is I believe entirely new, and the ſolution will afford amuſement to you and inſtruction to me.

Setting at my door one evening laſt ſummer, I took a ſilk handkerchief out of my pocket, and ſtretching a portion of it tight between my two hands, I held it up before my face and viewed, through the handkerchief, one of the ſtreet lamps which was about one hundred yards diſtant; expecting to ſee the threads of the handkerchief much magnified. Agreeably to my expectation I obſerved the ſilk threads magnified to the ſize of very coarſe wires; but was much ſurpriſed to find that, although I moved the handkerchief to the right and left before my eyes, the dark bars did not ſeem to move at all, but remained permanent before the eye. If the dark bars were occaſioned by the interpoſition of the magnified threads between the eye and the flame of the lamp, I ſhould have ſuppoſed that they would move and ſucceed each other, as the threads were made to move and paſs in ſucceſſion before the eye; but the fact was otherwiſe.

To account for this phenomenon exceeds my ſkill in *optics*. You will be ſo good as to try the experiment, and if you find the caſe truly ſtated, as I doubt not you will, I ſhall be much obliged by a ſolution on philoſophical principles. I am ſir, with great ſincerity,

Your moſt effectionate friend,
And very humble ſervant,
F. HOPKINSON.

The Anſwer, by Mr. RITTENHOUSE.

DEAR SIR,

THE experiment you mention, with a ſilk handkerchief and the diſtant flame of a lamp, is much more curious than one would at firſt imagine. For the object we ſee is not the web of the handkerchief magnified, but ſomething very different, as appears from the following conſiderations. 1ſt. A diſtinct image of any object, placed cloſe to the eye, cannot be formed by parallel rays, or ſuch as iſſue from a diſtant luminous point: for all ſuch rays, paſſing through the pupil, will be collected at the bottom of the eye, and there form an image of the luminous point. The threads of the handkerchief would only intercept part of the rays, and render the image leſs brilliant. 2dly. If the croſs bars we ſee were images of the ſilk threads, they muſt paſs over the retina, whilſt the threads are made to paſs over the pupil; but this, as you obſerve, does not happen; for they continue ſtationary. 3dly. If the image on the retina was a picture of the object before the eye, it muſt be fine or coarſe, according to the texture of the handkerchief. But it does not change with changing the ſilk, nor does it change on removing it farther from the eye. And the number of apparent threads remains the ſame, whether 10, 20, or 30 of the ſilk threads paſs acroſs the pupil at the ſame time. The image we ſee muſt therefore be formed in ſome different manner; and this can be no other than by means of the *inflection* of light in paſſing near the ſurfaces of bodies, as deſcribed by NEWTON.

It is well known in optics that different images of the different points of objects without the eye are formed on the retina by pencils of rays, which, before they fall on the eye, are inclined to each other in ſenſible angles. And the great uſe of teleſcopes is to encreaſe theſe angles, regularly, in a certain ratio; ſuffering ſuch rays as were parallel

parallel before they enter the teleſcope to proceed on, parallel, after paſſing through it. The extended image which we ſee in this experiment muſt therefore be formed by pencils of rays, which before they entered the eye, had very conſiderable degrees of inclination with reſpect to each other. But coming from a ſmall diſtant flame of a lamp, they were nearly parallel before they paſſed through the ſilk handkerchief. It was therefore the threads of ſilk which gave them ſuch different directions.

Before the ſilk is placed to the eye, parallel rays of light will form a ſingle lucid ſpot, as at A, Plate III. Figure 16. And this ſpot will ſtill be formed afterwards by ſuch rays as paſs through the little meſhes uninfluenced by the threads. But ſuppoſe the perpendicular threads by their action on the rays, to bend a part of them one degree to the right and left, another part two degrees; there will now be four new images formed, two on each ſide of the original one at A. By a ſimilar action of the horizontal threads, this line of five lucid points will be divided into five other lines, two above and two below, making a ſquare of twenty-five bright ſpots, ſeparated by four perpendicular dark lines and four horizontal ones; and theſe lucid ſpots and dark lines will not change their places on moving the web of ſilk over the eye parallel to any of its threads. For the point of the retina on which the image ſhall fall is determined by the incidence of the rays, with reſpect to the axis of the eye, before they enter, and not by the part of the pupil through which they paſs.

In order to make my experiments with more accuracy, I made a ſquare of parallel hairs about half an inch each way. And to have them nearly parallel and equidiſtant, I got a watchmaker to cut a very fine ſcrew on two pieces of ſmall braſs wire. In the threads of theſe ſcrews, 106 of which made one inch, the hairs were laid 50 or 60 in number. Looking through theſe hairs at a ſmall opening in the window ſhutter of a dark room, $\frac{1}{30}$ of an inch wide

and

and three inches long, holding the hairs parallel to the ſlit, and looking toward the ſky, I ſaw three parallel lines, almoſt equal in brightneſs, and on each ſide four or five others much fainter and growing more faint, coloured and indiſtinct, the farther they were from the middle line, which I knew to be formed by ſuch rays as paſs between the hairs uninfluenced by them. Thinking my apparatus not ſo perfect as it might be, I took out the hairs and put in others, ſomething thicker, of theſe 190 made one inch, and therefore the ſpaces between them were about the $\frac{1}{250}$ part of an inch. The three middle lines of light were now not ſo bright as they had been before, but the others were ſtronger and more diſtinct, and I could count ſix on each ſide of the middle line, ſeeming to be equally diſtant from each other, eſtimating the diſtance from the centre of one to the centre of the next. The middle line was ſtill well defined and colourleſs, the next two were likewiſe pretty well defined, but ſomething broader, having their inner edges tinged with blue and their outer edges with red. The others were more indiſtinct, and conſiſted each of the priſmatic colours, in the ſame order, which by ſpreading more and more, ſeemed to touch each other at the fifth or ſixth line, but thoſe neareſt the middle were ſeparated from each other by very dark lines, much broader than the bright lines.

Finding the beam of light which came through the window ſhutter divided into ſo many diſtinct pencils, I was deſirous of knowing the angles which they made with each other. For this purpoſe I made uſe of a ſmall priſmatic teleſcope and micrometer, with which I was favoured by Dr. Franklin. I faſtened the frame of parallel hairs before the object glaſs, ſo as to cover its aperture entirely. Then looking through the teleſcope, I meaſured the ſpace between the two firſt ſide lines, and found the angular diſtance between their inner edges to be $13'$, $15''$; from the middle of one to the middle of the other $15'$, $30''$, and from

from the outer edge of one, to the outer edge of the other 17′, 45″. In the firſt caſe I had a fine blue ſtreak in the middle of the object, and in the laſt a red ſtreak. The other lines were too faint, when ſeen through the teleſcope, to meaſure the angles they ſubtended with accuracy, but from ſuch trials as I made I am ſatisfied that from the ſecond line on one ſide to the ſecond on the other ſide, and ſo on, they were double, triple, quadruple, &c. of the firſt angles.

It appears then that a very conſiderable portion of the beam of light paſſed between the hairs, without being at all bent out of its firſt courſe; that another ſmaller portion was bent at a medium about 7′, 45″ each way; the red rays a little more, and the blue rays a little leſs; another ſtill ſmaller portion 15′, 30″; another 23′, 15″, and ſo on. But that no light, or next to none, was bent in any angle leſs than 6′, nor any light of any particular colour, in any intermediate angle between thoſe which ariſe from doubling, tripling, &c. of the angle in which it is bent in the firſt ſide lines.

I was ſurprized to find that the red rays are more bent out of their firſt direction, and the blue rays leſs; as if the hairs acted with more force on the red than on the blue rays, contrary to what happens by refraction, when light paſſes obliquely through the common ſurface of two different mediums. It is, however, conſonant to what Sir Iſaac Newton obſerves with reſpect to the fringes that border the ſhadows of hairs and other bodies; his words are, "And therefore the hair in cauſing theſe fringes, "acted alike upon the red light or leaſt refrangible rays "at a greater diſtance, and upon the violet or moſt re-"frangible rays at a leſs diſtance, and by thoſe actions "diſpoſed the red light into larger fringes, and the violet "into ſmaller fringes."

By purſuing theſe experiments it is probable that new and intereſting diſcoveries may be made, reſpecting the

properties of this wonderful ſubſtance, light, which animates all nature in the eyes of man, and perhaps above all things diſpoſes him to acknowledge the Creator's bounty. But want of leiſure obliges me to quit the ſubject for the preſent.

I am, dear ſir, your affectionate friend,
And very humble ſervant,
DAVID RITTENHOUSE.

N° XXV.

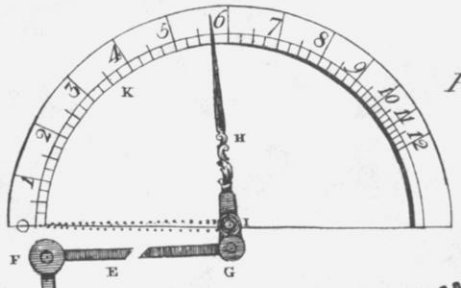
An Enquiry into the Cauſe of the Increaſe of Bilious and Intermitting Fevers in Pennſylvania, with Hints for preventing them. By BENJAMIN RUSH, M. D. *Profeſſor of Chemiſtry in the Univerſity of Pennſylvania.*

Read December 16, 1785.

IT has been remarked, that Pennſylvania for ſome years paſt has become more ſickly than formerly. Fevers which a few years ago appeared chiefly on the banks of creeks and rivers, and in the neighbourhood of mill-ponds, now appear in parts remote from them all, and in the higheſt ſituations. This change with reſpect to the healthineſs of our country, may be traced to the three following cauſes.

1. The eſtabliſhment and increaſe of mill-ponds. There are whole counties in Pennſylvania in which intermittents were unknown, until the waters in them were dammed, for the purpoſe of erecting mill-ponds.

2. The cutting down of wood, under certain circumſtances, tends to render a country ſickly. It has been remarked that intermittents on the ſhores of the Suſquehannah have kept an exact pace with the paſſages which have been opened for the propagation of marſh effluvia, by cutting



Page. 159.

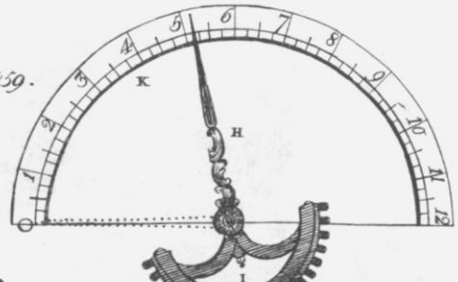


Fig. 1.

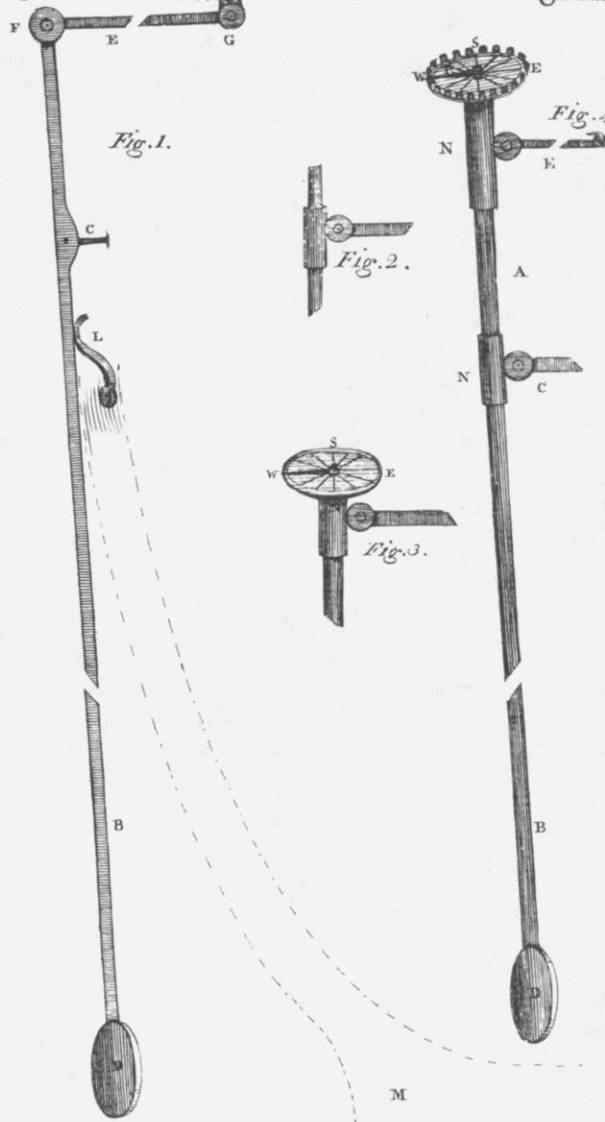


Fig. 2.

Fig. 3.

Fig. 4.

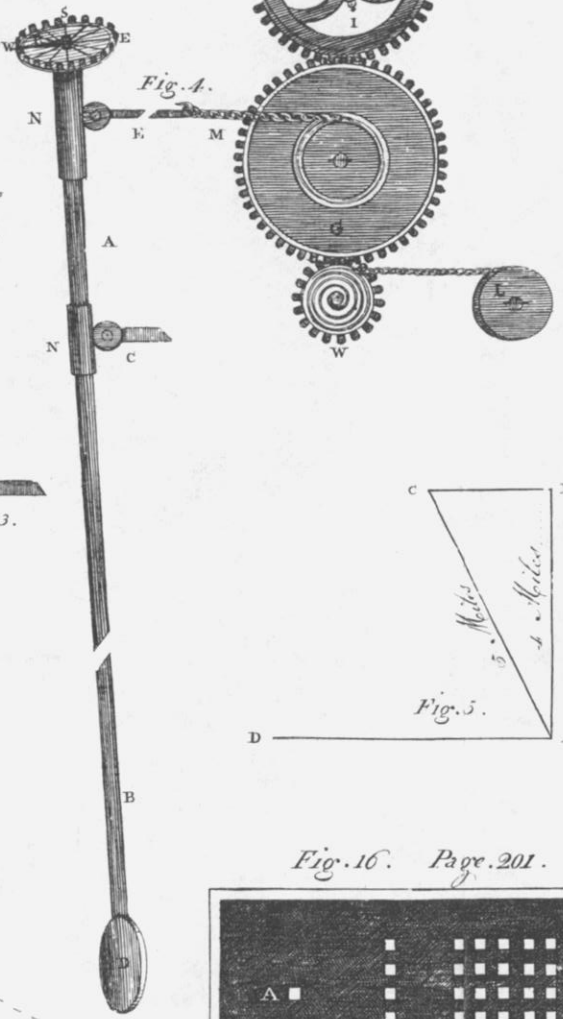


Fig. 5.

Fig. 16. Page. 201.

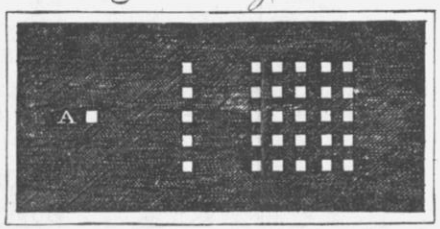


Fig. 6.

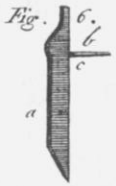


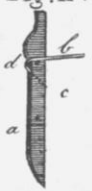
Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.



Page 185.

Fig. 12.

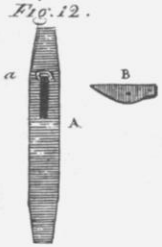


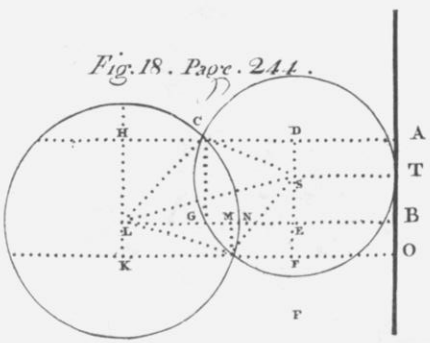
Fig. 13.

Fig. 14.

Fig. 15.

Fig. 17.

Fig. 18. Page. 244.



Jn.t Peyrard sculp.t